SUMMARY

According to one aspect of this disclosure, there is provided an ultra-high density energy-storage apparatus and system with high lifetime (e.g., in the range of hundreds of thousands cycles) and very high energy/power density.

According to one aspect of this disclosure, there is provided an electrical-energy storage device for storing electrical energy for use as a power source, the electrical-energy storage device comprising: a conductive or semi-conductive first metasurface layer comprising a plurality of nano-scale or micro-scale first structures with a nano-scale or micro-scale first spacing; a conductive or semi-conductive second metasurface layer comprising a plurality of nano-scale or micro-scale second structures with a nano-scale or micro-scale second spacing; and a dielectric layer sandwiched between the first and the second metasurface layers for electrically insulating the first metasurface layer from the second metasurface layer; wherein the plurality of first structures and the plurality of second structures extend into each other without electrical contact therewith.

In some embodiments, the first metasurface layer comprises a plurality of nano-scale or micro-scale first structures; the second metasurface layer comprises a plurality of nano-scale or micro-scale second structures; and the first and the second structures extending into each other without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of recesses at distal ends thereof; and at least a second set of the second structures are received in the recesses of the first structures without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of first rods having recesses at distal ends thereof; and at least a portion of the second structures are received in the recesses of the first rods without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of first rods; and the second structures comprise a plurality of second rods interleaved with the first rods.

In some embodiments, at least a first set of the first and the second structures has a circular, elliptical, or rectangular cross-section.

In some embodiments, one or more dimensions of each of the first and the second structures are in a nanometer range or in a micrometer range.

In some embodiments, the thicknesses of the first and the second structures are in the nanometer range or in the micrometer range.

In some embodiments, the electrical-energy storage device further comprising at least one of: a first electrode coupled to the first metasurface layer; and a second electrode coupled to the second metasurface layer.

In some embodiments, at least one of the first and the second metasurface layers comprises an electrically conductive base forming an electrode.

According to one aspect and in some embodiments, there is provided a method of fabricating an electrical-energy storage device; the method comprises: (i) depositing a first conductive layer onto a substrate; (ii) spin-coating a photoresist layer onto the conductive layer;

WHAT IS CLAIMED IS:

1. An electrical-energy storage device for storing electrical energy for use as a power source, the electrical-energy storage device comprising:

a conductive or semi-conductive first metasurface layer comprising a plurality of nano-scale or micro-scale first structures with a nano-scale or micro-scale first spacing;

a conductive or semi-conductive second metasurface layer comprising a plurality of nano-scale or micro-scale second structures with a nano-scale or micro-scale second spacing; and

a dielectric layer sandwiched between the first and the second metasurface layers for electrically insulating the first metasurface layer from the second metasurface layer;

wherein the plurality of first structures and the plurality of second structures extend into each other without electrical contact therewith.

2. The electrical-energy storage device of claim 1, wherein the first structures comprise a plurality of recesses at distal ends thereof; and

wherein at least a second set of the second structures are received in the recesses of the first structures without electrical contact therewith.

3. The electrical-energy storage device of claim 1, wherein the first structures comprise a plurality of first rods having recesses at distal ends thereof; and

wherein at least a portion of the second structures are received in the recesses of the first rods without electrical contact therewith.

4. The electrical-energy storage device of any one of claims 1 to 3, wherein at least a first set of the first and the second structures has a circular, elliptical, or rectangular cross-section.

5. The electrical-energy storage device of claim 1, wherein the thicknesses of the

first and the second structures are in the nanometer range or in the micrometer range.

6. The electrical-energy storage device of any one of claims 1 to 5 further comprising at least one of:

a first electrode coupled to the first metasurface layer; and

a second electrode coupled to the second metasurface layer.

7. The electrical-energy storage device of any one of claims 1 to 6, wherein at least one of the first and the second metasurface layers comprises an electrically conductive base forming an electrode.